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RESEARCH ARTICLE

Natural forests health assessment in 'Parangalitsa' Reserve, Rila Mountain

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Abstract

Health status assessment and monitoring in natural forest stands were conducted in 2024 in the 'Parangalitsa' Reserve (Rila Mountain, Southwest Bulgaria). A series of subsequent terrain observations were performed in the protected forest area. As a result, 16 fungal pathogens and 17 insect pests were identified as causing damage to the main tree species – Norway spruce (*Picea abies*), silver fir (*Abies alba*), Scots pine (*Pinus sylvestris*), and European beech (*Fagus sylvatica*). Among the parasitic fungi, *Armillaria mellea*, *Heterobasidion annosum, Fomitopsis pinicola,* and *Fomes fomentarius* were identified as the most destructive. Fir broom rust *Melampsorella elatina* was the causal agent for perennial infections in silver fir trees. Seventeen insect species from six families and five orders were established on *Abies alba*, *Picea abies,* and *Pinus sylvestris*. Attacks of the European bark beetle *Ips typographus* formed the reserve's main disturbance in the Norway spruce forests. Bark beetles *Ips acuminatus* and *Pityokteines curvidens* were the most destructive xylophages on Scots pine and silver fir trees, respectively. In high population density, the three aggressive xylophages could cause severe damage and drying of the attacked stands.

Keywords

Protected forest area, 'Parangalitsa' Reserve, Rila Mountain, health condition, biological factors

Introduction

The health status assessment of protected forest areas involves a systematic approach to identifying and characterising biotic and abiotic threats to forest stands in their natural environment. The consequences of such threats include severe attacks of bark

beetles, stem and root rot diseases, parasitic pathogens, and abiotic injuries. Health status assessments require attention to be given first to the most important pests and diseases that can result in the worst health-related outcomes. Indicators of the health status deterioration usually include an assessment of risk factors and an evaluation of the degree of damage caused. These factors include the risk of forest fires, biotic disturbances caused by pest outbreaks and invasive pathogens, and severe weather events. Bark beetle attacks and long-term drought stress induced by less favourable climate conditions, or weakened by pathogens and other biotic agents, are the most important causes of forest disturbances and can predispose trees to mortality. Outbreaks of bark beetles affect forests already stressed by drought (Gaylord et al., 2013).

Tree diversity is an important determinant of the ecological stability or vulnerability of the forests against disturbances, such as insect outbreaks or pathogen epidemics (Witzell et al., 2022). Tree crown condition, assessed in terms of defoliation, discoloration, and biotic or abiotic damage, is regarded as one of the most important indicators of forest health status. Health of forests is strongly influenced by extreme temperatures (Michel et al., 2024). In recent decades, forest stands have been affected by severe droughts, widespread wildfires, a series of windstorms, rapidly expanding bark beetle infestations, and several other pest and disease outbreaks (Seidl et al., 2017; Lindner, Verkerk, 2021).

The sustainability of natural forests in Bulgaria is a priority of national policy. To be sustainable, forest scientists and ecologists need information on the factors that influence forest health conditions. The protected natural area 'Parangalitsa' in Rila National Park was declared as a reserve in 1933. In 1977, UNESCO announced it as a biosphere reserve that includes 1487.3 ha of forest and subalpine territories. Norway spruce (*Picea abies* (L.) Karst.) is the most abundant tree species, followed by silver fir (*Abies alba* Mill.), European beech (*Fagus sylvatica* L.), Scots pine (*Pinus sylvestris* L.), etc.

Investigation of the long-term disturbance history of old protected forests dominated by Norway spruce in Parangalitsa Reserve were carried out to reconstruct the history of wind, insect, and fire disturbances (Panayotov et al., 2011). Over the past 150 years the wind has been the most important disturbance agent in these ecosystems. Pure coniferous forest stands were more affected by blowdowns than mixed coniferous–deciduous forest stands. Although bark beetle (*Ips typhographus*) populations were large enough to cause mortality of vital trees, they were not high enough to cause epidemic proportions during recent decades (Panayotov et al., 2011; Mirchev et al., 2023).

The long-term observations have made it possible to determine the status of forest health (ICP Forests, 2021). A long-term survey (1988-2022) on the health status of trees in a mixed Norway spruce-silver fir permanent sample plot was carried out as a part of the large-scale network for monitoring the health status of forest ecosystems to the International Cooperative Program 'Forests' (Georgieva et al., 2023). Damage caused by attacks of bark beetles (Curculionidae), fungal diseases, and wet snow injuries, were reported annually. Among the fungal pathogens, stem rots caused by

the wood-destroying fungus *Fomitopsis pinicola* predominantly developed in Norway spruce trees. Harmful impact on trees was caused by the most aggressive bark beetles: *I. typographus* on Norway spruce and *Pityokteines curvidens* on silver fir trees (Mirchev et al., 2023).

Due to restricted protection regimes in areas of high conservation value, the implementation of silvicultural measures is impossible in them. Silvicultural management would improve the forests' condition and limit the harmful impact and unregulated spread of emerged fungal pathogens and insect pests. At the same time, these areas serve as valuable sites for monitoring natural processes and act as reference points for ecological studies. A comparison between the past and the present species composition, could allow us to outline the dynamics of these forests and to explain the present decline of silver fir as a part of this dynamic.

The aim of this study was to present the results of the monitored natural forest stands in 'Parangalitsa' Reserve and to identify the complex of the main abiotic and biotic stressors contributing to the deterioration of the forest stands in the reserve.

Material and methods

Assessment of the health status of Norway spruce (*P. abies*), silver fir (*A. alba*), European beech (*F. sylvatica*) and Scots pine (*P. sylvestris*) stands was conducted in five natural ecosystems plots located in 'Parangalitsa' Reserve in May-October, 2024. Field expeditions were conducted in experimental sites along an altitudinal transaction between 1350 and 1650 m a.s.l. Particular attention was paid to xylophagous attacks. Root and stem rot diseases caused by wood-destroying fungi were established by the presence of fruiting bodies. The number of dead trees was determined.

The health status of individual tree species was assessed by surveying five sample plots covering an area of 1 to 1.5 ha and from 40 to 100 pcs. trees from the dominant tree species. Within each plot the severity of decline symptoms on trees was measured (Eichhorn et al., 2020). The identification of diseases was carried out in the laboratory of phytopathology and entomology of Forest Research Institute – Bulgarian Academy of Sciences in Sofia, using macro- and microscopic methods, determining the pathogens and pests.

Results

In 2024, damage caused by biotic factors in 'Parangalitsa' Reserve was evaluated. The fungal pathogens causing diseases on the stems and roots predominated in the sample plots of Norway spruce and silver fir. Sixteen species of fungal parasitic pathogens were identified (Table 1). Among them, three wood-destroying fungal pathogens *Heterobasidion annosum*, *Armillaria mellea* and *Fomitopsis pinicola* were found as the most destructive, causing root and stem rot diseases on 37.4% of coniferous trees (Fig. 1A-D).

Table 1. Species composition and harmfulness of fungal pathogens in 'Parangalitsa' Reserve

Species	Plant host	Plant part	Harm-fulness*	Occur-rence**
Armillaria mellea (Fr.:Fr.) Staude, Bref.	*Picea abies*, *Fagus sylvatica*	root, stem	++	++
Biscogniauxia nummularia (Bull.) Kuntze	*Fagus sylvatica*	stem	++	++
Cenangium ferruginosum Fr.	*Pinus sylvestris*	branches	+	+
Cyclaneusma minus (Butin) DiCosmo, Peredo & Minter	*Pinus sylvestris*	needles	+	+
Diplodia sapinea (Fr.) Fuckel	*Pinus sylvestris*	branches	++	++
Fomitopsis pinicola (Sw.) Karst.	*Picea abies*	stem	+	++
Fomes fomentarius (L.) Fr.	*Fagus sylvatica*	stem	++	++
Herpotrichia nigra Hartig.	*Abies alba*	needles	+	+++
Heterobasidion annosum (Fr.:Fr.)	*Picea abies*	root, stem	++	++
Laetiporus sulphurous Murrill	*Picea abies*	stem	+	+
Lophodermium piceae (Fuckel) Höhn.	*Picea abies*	needles	+	+
Lophodermium pinastri (Schrader) Chevalier	*Pinus sylvestris*	needles	+	++
Lophodermium seditiosum Minter, Staley & Millar	*Pinus sylvestris*	needles	++	+
Melampsorella elatina (Alb. & Schwein.) Arthur	*Abies alba*	branches, stem	+	+++
Pholiota squarrosa (Oeder) Kumm.	*Picea abies*	base of stem	++	+
Stereum rugosum (Persoon) Fries	*Fagus sylvatica*	stem	+	+

***Harmfulness:** + weak parasite; ++ destructive parasitic pathogen; ****Occurrence:** + single; ++ frequent; +++ very frequent.

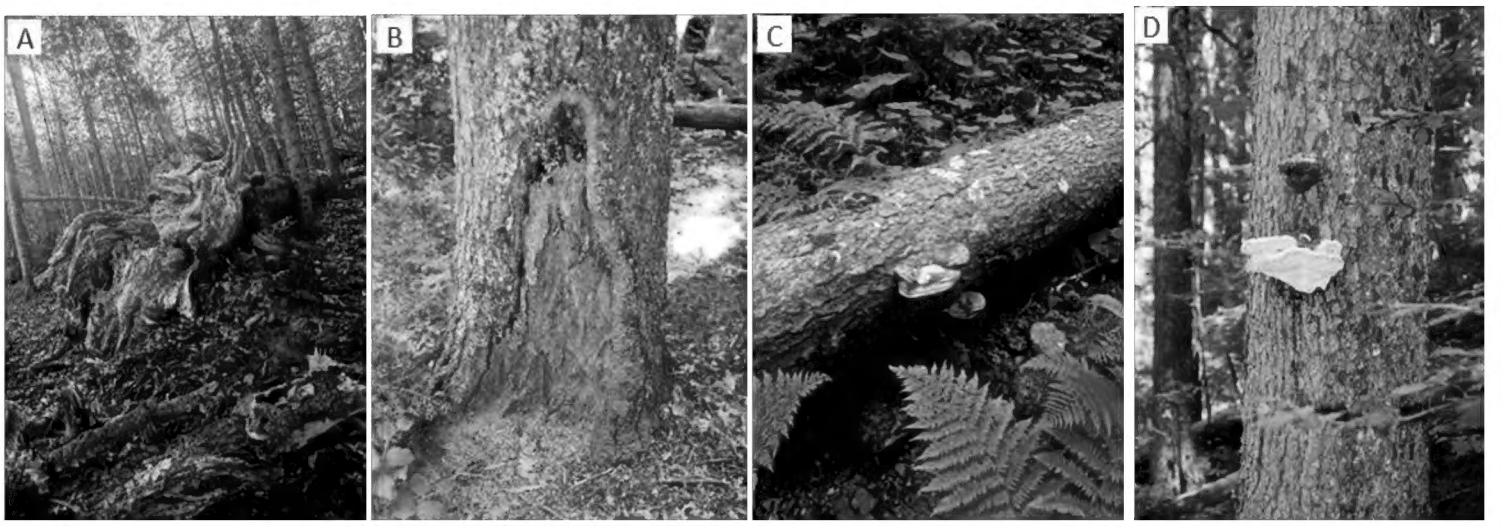

Fig. 1. Trees infected by wood-decaying fungal pathogens established in 'Parangalitsa' Reserve: *Heterobasidion annosum*, *Armillaria mellea*, *Fomitopsis pinicola*

The wood-destroying fungal pathogens were responsible for different types of rot. *Heterobasidion annosum* caused brown root rot, most likely in the centre part of the Norway spruce stems (Fig. 1A). *Armillaria mellea* caused white decay on the roots and stems developed as peripheral rot (Fig. 1B). As both pathogens had entered a

Fig. 2. Parasitic fungal pathogen *Melampsorella elatina* established in 'Parangalitsa' Reserve

host tissue at the soil line into the roots, where they caused extensive damage. The pathogens *Laetiporus sulphurous,* and *Pholiota squarrosa* were identified on mature trees with dieback symptoms. The trees infected by rot disease were fallen or broken and attacked by stem boring insects.

The highest incidences of observed disease were due to fir broom rust *Melampsorella elatina* (Pucciniastraceae), affecting 84.5% of silver fir (*A. alba*) trees. *M. elatina* caused yellow upright witches' brooms on apical branches, resulting in top dieback (Fig. 2). On the infected stems, the bark covering the section of infections become cracked and cankered. Cracked bark in old brooms provided an entrance for canker pathogens and wood decay fungi.

In European beech (*F. sylvatica*), the highest percentage (43%) of stems were affected by the development of *Fomes fomentarius*. Numerous fruiting bodies of the fungus were found mostly on the old dead trees in the reserve. On mature and dead trees symptoms of necrosis caused by the latent parasite fungus *Biscogniauxia nummularia* were found.

Fungal pathogen *Cyclaneusma minus* was the most common endophyte affecting needles of pine trees in the reserve. *Diplodia sapinea*, *Lophodermium pinastri*, *L. seditiosum* and *Cenangium ferruginosum* were found causing diseases on needles and branches. Conversely, infection with a root pathogen such as the honey fungi *A. mellea* and *H. annosum* were not found.

Seventeen insect species from six families and five orders were established on *Abies alba*, *Picea abies* and *Pinus sylvestris* (Table 2). One species (*Cydia strobilella*) was conophage on *Picea abies*, three species (*Phyllaphis fagi*, *Orchestes fagi* and *Mikiola fagi*) were phyllophages on *Fagus sylvatica* (Fig. 3), and 13 species and subspecies were xylophages on stems and branches of the hosts. Eleven xylophagous insects attacked live trees, and two species (*Hylurgops palliates* and *Rhagium inquisitor*) were saprophagous, developing in dead wood.

Table 2. Species composition and harmfulness of phytophagous insects in 'Parangalitsa' Reserve

ORDER, Family, Species	Plant host	Plant part	Harm-fulness*
HEMIPTERA			
Aphididae			
Phyllaphis fagi (Linnaeus, 1761)	*Fagus sylvatica*	leaves	+
COLEOPTERA			
Curculionidae			
Hylurgops palliates (Gyllenhal, 1813)	*Picea abies*	stem, branches	-
Ips acuminatus (Gyllenhal, 1827)	*Pinus sylvestris*	top of stem, branches	++
Ips typographus (Linnaeus, 1758)	*Picea abies*	base of stem	++
Orchestes fagi (Linnaeus, 1758)	*Fagus sylvatica*	leaves	+
Pityogenes chalcographus (Linnaeus, 1760)	*Abies alba*, *Picea abies*, *Pinus sylvestris*	stem, branches	+
Pissodes harcyniae (Herbst, 1795)	*Picea abies*	stem	+
Pissodes piniphilus (Herbst, 1797)	*Pinus sylvestris*	stem	+
Pityokteines curvidens (Germar, 1823)	*Abies alba*	stem	++
Tomicus piniperda (Linnaeus, 1758)	*Pinus sylvestris*	stem	+
Cerambycidae			
Monochamus galloprovincialis pistor (Germar, 1818)	*Pinus sylvestris*	stem	+
Monochamus sutor sutor (Linnaeus, 1758)	*Picea abies*	stem	+
Tetropium castaneum (Linnaeus, 1758)	*Picea abies*	stem	+
Rhagium inquisitor Linnaeus, 1758	*Abies alba*, *Picea abies*		-
LEPIDOPTERA			
Tortricidae			
Cydia strobilella (Linnaeus, 1758)	*Picea abies*	cones, seeds	+
HYMENOPTERA			
Siricidae			
Urocerus gigas (Linnaeus, 1758)	*Picea abies*, *Pinus sylvestris*	stem	+
DIPTERA			
Cecidomyiidae			
Mikiola fagi (Hartig, 1839)	*Fagus sylvatica*	leaves	+

***Harmfulness:** - saprophagous; + slight damages; ++ severe damages (destructive pest)

Three species (*Ips acuminatus*, *I. typographus* and *Pityokteines curvidens*) were the most aggressive insect pests (Table 2, Fig. 4). In 'Parangalitsa' Reserve, these calamitous insects attacked and destroyed living trees, forming bark beetle spots. The other xylophagous species (*Pityogenes chalcographus*, *Pissodes harcyniae*, *P. piniphilus*, *Tomicus piniperda*, *Monochamus galloprovincialis pistor*, *M. sutor sutor*, *Tetropium castaneum* and *Urocerus gigas*) developed on weakened and dying trees.

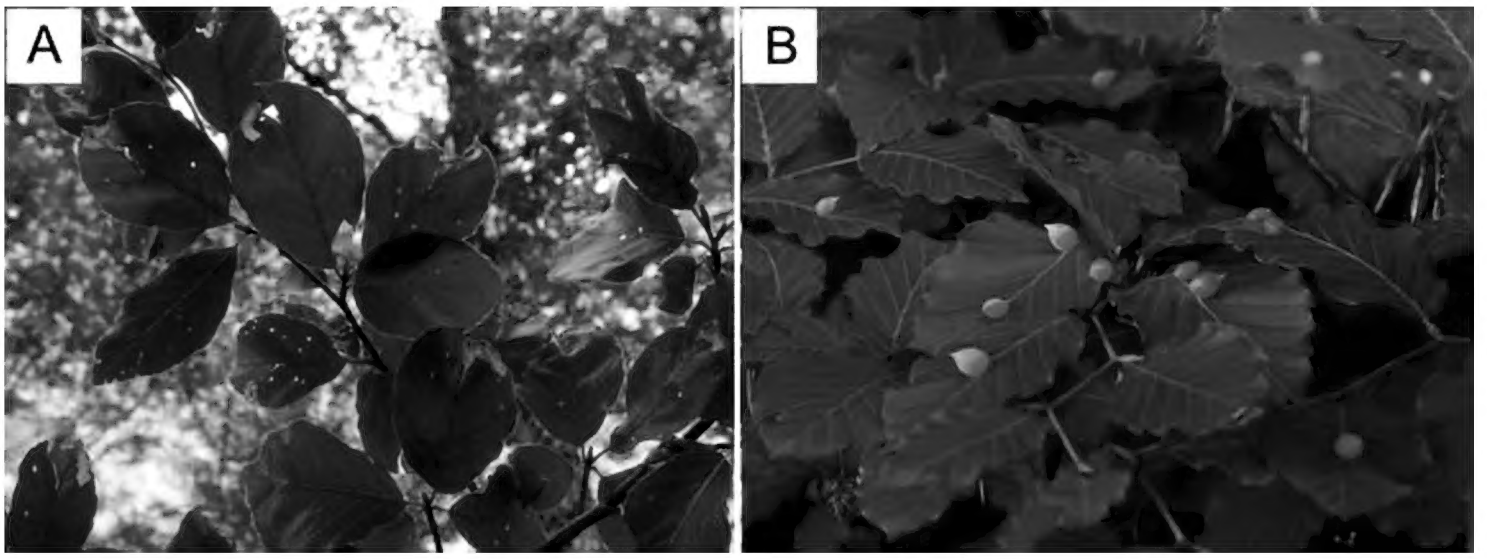

Fig. 3. Damage caused by phyllophagous insects on *F. sylvatica*: A – *Orchestes fagi*; B – *Mikiola fagi*

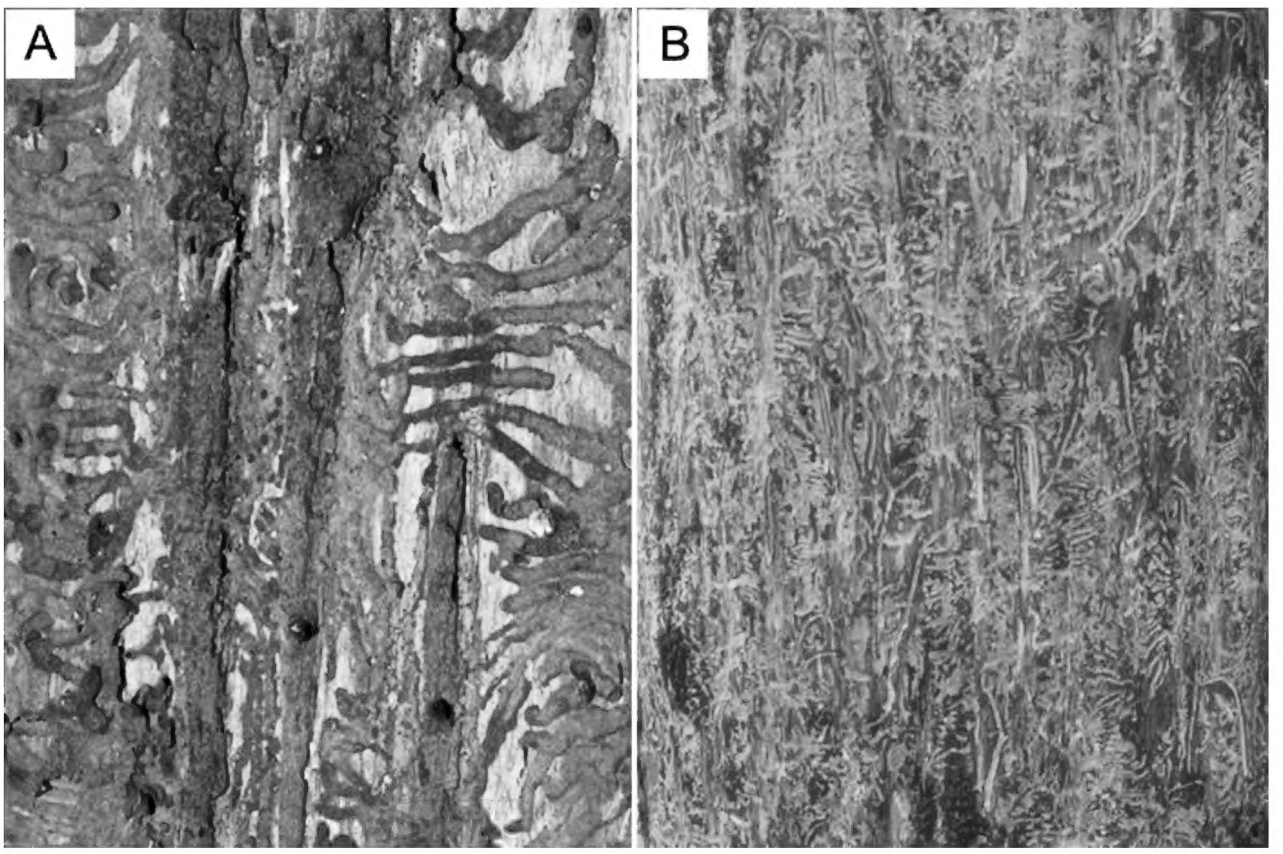

Fig. 4. Damage caused by bark beetles: A – *Ips typographus* on *P. abies*; B – *Pityokteines curvidens* on *A. alba*

Discussion

Forest ecosystems in the protected areas follow the course of natural biological processes, without anthropogenic intervention in them. Among the most significant anthropogenic threats are fires that could destroy or drastically deteriorate the habitats of a significant number of plant species, including those of conservation importance. The ecological role of the naturally protected forest stands, as well as their role in economic and recreational use, is strongly influenced by the uncontrolled development of diseases, pest outbreaks, and adverse climatic events. In recent years, in

Bulgaria, forest ecosystems have been experiencing the introduction and subsequent strong spread of exotic pests and pathogens, affecting the structure and composition of natural forest ecosystems (Georgieva, 2020a).

Increasing temperatures and lack of precipitation contribute to the expansion or contraction of the distribution area of diseases and pest attacks in the upper altitudes in the mountains. Prolonged periods of high temperatures and reduced amounts of precipitation during the vegetation seasons have a negative impact on the physiological state of forests, increasing their vulnerability to attacks by diseases and pests (Santini, Ghelardini, 2015).

Reduced summer rainfall and drought stress increase the susceptibility of conifers to infection with root rot pathogens such as *Heterobasidion annosum* and *Armillaria mellea*, as well as to tree diebacks resulting from the development of invasive fungal pathogens and insect pests. According to Garbelotto & Gonthier (2013), *H. annosum* plays a less dangerous role in natural ecosystems than in managed forest stands. In natural stands the pathogen affects species composition, stand density and structure, the direction and rate of forest succession (Garbelotto, 2004). In 'Parangalitsa' Reserve the main pathogens that impacted the health status of Norway spruce (*Picea abies*) trees were *H. annosum* and *A. mellea*, causing root and stem rot.

Silver fir stands showed sensitivity to biotic and abiotic damage in 'Parangalitsa' Reserve. The long-term monitoring assessment showed severe damage in 1990, 1998, and 2001-2005 (Rossnev, Petkov, 1994; Rossnev, Pavlova, 2006). A tendency towards deterioration of their health status has been established for the last ten years (Georgieva et al., 2023). The reasons for the process and its dynamics were due to the complex interaction of stress factors such as prolonged droughts, which subsequently favours the development of parasitic fungi and insect pests. In the present study, the broom rust caused by the parasitic fungus *Melampsorella elatina* was identified most often on silver fir trees growing at the altitude between 1300-1400 m a.s.l. In Bulgaria, the parasite mainly causes damage to silver fir stands growing in the middle mountain belt under relatively cool and humid climatic conditions (Stancheva, Rosnev, 2005; Rosnev, Petkov, 1994).

In coniferous ecosystems the development of deterioration process most often was a result of the complex impact of abiotic and biotic factors (Rosnev et al., 2008, 2009). Prolonged droughts, especially during the growing season, cause weakening of trees and an increase in their susceptibility to diseases and pest attacks. A tendency towards strong thinning of the Scots pine crowns caused by the invasive fungal pathogen *Lecanosticta acicola* (von Thümen) Sydow has been observed in South Bulgaria since 2020 (Georgieva, 2020b). In 'Parangalitsa' Reserve needle blight diseases caused by the invasive pathogens were not found. The identified damage on the needles was most often caused by the pathogens *Cyclaneusma minus*, *Lophodermium pinastri*, *L. seditiosum* and on the branches – by *Cenangium ferruginosum*.

Numerous herbivorous insects are associated with woody and shrubby vegetation, the most of which are saprophagous and not particularly dangerous to host plants.

For example, 21 species of the Cerambycidae family have been reported in the 'Parangalitsa' Reserve (Georgiev et al., 2021). The three species – *Ips acuminatus*, *I. ypographus*, and *Pityokteines curvidens* (Table 2) – pose the greatest threat to forest stands. *Pityokteines curvidens* has been identified as an economically significant and destructive pest in *Abies alba* stands in Bulgaria (Tzankov et al., 1994).

Ips acuminatus has been identified as the main cause of attacks and drying of Scots pine stands in Europe (Grégoire, Evans, 2004), including Bulgaria, especially after windstorms and other natural disturbances (Stefanov, 1946; Tsankov, 1961, etc.).

Ips typographus is the most destructive bark beetle in spruce forests in Europe, where it destroyed about 100 million m^3 of mature spruce stands in the 20th century (CAB International, 2021). In Bulgaria, strong outbreaks of the pest occurred after the windstorms in 1962 in 'Parangalitsa' Reserve (Tsankov, Mirchev, 1985, 1986, 1991) and in 2001 in 'Bistrishko Branishte' Biosphere Reserve in Vitosha Mountain. (Georgiev et al., 2006; Georgieva et al., 2023).

Conclusion

Health status assessment and monitoring of deteriorated natural forest stands in 'Parangalitsa' Reserve in Rila Mountain (Bulgaria) was conducted in 2024. As a result, insect pests and parasitic fungi were identified in the studied plots focusing on Norway spruce (*Picea abies*), silver fir (*Abies alba*), European beech (*Fagus sylvatica*), and Scots pine (*Pinus sylvestris*). The predominant number of pests included bark beetles (Curculionidae), with the most dangerous being *Ips typographus* on Norway spruce, *Ips acuminatus* on Scots pine, and *Pityokteines curvidens* on silver fir. Among the parasitic fungi, species *Armillaria mellea*, *Heterobasidion annosum*, *Fomitopsis pinicola*, *Fomes fomentarius*, were identified as the most destructive. The fir broom rust caused by the parasitic fungus *Melampsorella elatina* was mostly identified on silver fir trees growing at the altitude between 1300-1400 m a.s.l. Necrosis caused by the latent parasitic fungus *Biscogniauxia nummularia* was found on weakened and dead beech trees. Further monitoring of the health status of tree species that form natural ecosystems in the 'Parangalitsa' Reserve would provide valuable insights into the ecological processes influencing forest dynamics, biodiversity, and overall ecosystem resilience, while protected areas could be used as a reference.

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